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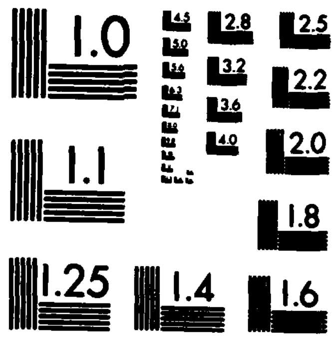

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TIME DOMAIN ELECTROMAGNETIC WAVES IN MULTILAYERED MEDIA

Department of the Army
Army Research Office
Contract DAAG 29-85-K-0079

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prepared by

J. A. Kong

Principal Investigator

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SUMMARY

This work has

With the support of the ARO Contract DAAG 29-85-K-0079, we have (1) modeled and calculated the impedance parameters of strip lines with perpendicularly crossing strips and computed the transient response on such structures, (2) analyzed the effects of periodical meshed ground planes on signal propagation, (3) generalized the method of characteristics for signal propagation on nonuniformly coupled transmission lines, (4) studied the transient response of arbitrary source excitation on two-layer media, and (5) studied the models of vias for interchip connections.

In multilayered integrated circuits, it is not unusual that strip lines are placed at different heights, running parallel or perpendicular to each other. We have investigated the capacitances associated with two offset parallel strips at different heights between ground planes using conformal mapping approach. In addition, parallel-plate lines with transverse ridges serve as approximations to parallel strips with perpendicularly crossing strips on top. We treated it as a distributed circuit consisting of transmission lines segments with periodical capacitive loading. In order to calculate the coupling between two lines, we reduced this structure to equivalent even mode and odd mode circuits. The Laplace transform approach are then easily applied to find out the transient response. The numerical computation carried out for various environments shows that the crossing strips will cause serious trouble for signals with a rise time of less than 50ps to propagate along a distances of 2cm or longer.

We have also applied the technique of wave transmission matrices in periodic structures to examine transmission and reflection properties in striplines under the influence of meshed ground planes. Responses at different frequencies are calculated, followed by numerical Fourier inversion to obtain the time-domain response. The resistances of ground planes and strips have been taken into account. The results support the conclusion of the aforementioned research.

Previously we devised a scheme that combines the method of characteristics and perturbational series to simplify the computation of the transient response in nonuniformly coupled transmission line systems, which are very good models for strip lines in the multilayered integrated circuits. A new transformation for decoupling equations is found which enables us to generalize this formulation to calculate the near-end and far-end crosstalks to very high accuracy, given any form of both capacitive and inductive coupling coefficients.

A general method of analyzing the time-domain bi-directional coupling of a pair of nonuniformly coupled dispersionless transmission lines is presented. The transmission line equations are decoupled using the method of characteristics and the equations are

solved iteratively. In the cases with linear loads. the unit-step response can be obtained in closed-form to the first order. and arbitrary excitations can be handled by convolution. Numerical integration for the cases with nonlinear loads is also shown to be more efficient than integration based on the original coupled partial differential equations.

Basically. vias in a multilayered integrated circuits are treated like transmission lines with loadings where they encounter holes in ground planes separating different layers. We have modeled a ground plane with a hole and a circular conductor at the center of the hole as a radial waveguide, which in turn is connected to the via. another section of transmission line. Thus by computing the characteristic impedance of the former, we have derived the equivalent load impedance of the via hole. The load impedance is one important parameter in calculating the transient propagation along vias.

The transient electromagnetic radiation by a vertical electric dipole on a two-layer medium is analysed using the double deformation technique, which is a modal technique based on identification of singularities in the complex frequency and wavenumber planes. Previous application of the double deformation technique to the solution of this problem is incomplete in the the early time response. In this paper we show that the existence of a pole locus on the negative imaginary frequency axis, which dominates the early time response, proves crucial in obtaining the solution for all times. A variety of combinations of paremeters are used to illustrate the double deformation technique, and results will be compared with those obtained via explicit inversion, and a single deformation method.

The double-deformation technique is a modal technique based on identifying and extracting singularities from the Fourier integrals in the complex frequency and wave number domains. With this method, we have been able to obtain both early and late time response for vertical electric dipole and line source excitations in a two-layer medium very efficiently. We have also discovered a general scheme of breaking up the integrands so that sources with arbitrary time and space dependences can be easily handled without sacrificing convergence.

Three methods are given, with which bounded electromagnetic sources can be decomposed into two parts radiating. respectively, TE and TM fields with respect to a given constant direction in space. Source equivalence and nonradiating sources are discussed and taken into account in the theory. which leads to a recursive method or two different differential equations for the TE and TM components of the original source. It is seen that for a point source, a decomposition can be made with the aid of a line source, a plane source. or a set of point sources. A combination of these is also possible. The result is discussed and the planar decomposition is seen to match to an earlier result given by Clemmow in 1963. Also, it is demonstrated that the general exact image expression for the Sommerfeld half-space problem can be obtained through the present decomposition method.

In order to investigate the validity of the quasi-TEM approximation for the time-domain wave propagation, we have developed an iterative approach to perform quasi-TEM analysis in the time-domain. By assuming first that the longitudinal field components are small, it is shown that the transversal components can be obtainted from statics equations analogous to those applied for sinusoidal steady states. They also lead to solutions to the propagation velocities and voltage distributions of diferent quasi-TEM modes. The convergence criterion is shown to depend upon the time derivative of signals and inhomogeneity of the media.

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